Effects of Different Magnitudes of Whole-Body Vibration on Arm Muscular Performance

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[1]*Laboratory of Physiology, European University Miguel de Cervantes, Valladolid, Spain;* [2]*Research Center on Physical Disability, ASPAYM Castilla y León, Valladolid, Spain; and* [3]*A.T. Still University, Mesa, Arizona*

Abstract

Marín, PJ, Herrero, AJ, Sáinz, N, Rhea, MR, and García-López, D. Effects of different magnitudes of whole-body vibration on arm muscular performance. *J Strength Cond Res* 24(9): 2506–2511, 2010—The purpose of this study was to analyze the effects of different vibration magnitudes via feet on the number of repetitions performed, mean velocity, and perceived exertion during a set of elbow-extension exercise to failure (70% 1 repetition maximum [1RM] load). Twenty recreationally active students (14 men and 6 women) performed, in 3 different days, 1 elbow-extension set applying randomly 1 of the 3 experimental conditions: high magnitude (HM; 50 Hz and 2.51 mm_{p-p}; 98.55 $m\cdot s^{-2}$), low magnitude (LM; 30 Hz and 1.15 mm_{p-p}; 20.44 $m\cdot s^{-2}$) or control (Control, without vibration stimulus). Results indicate that the vibration via feet provides superimposed stimuli for elbow-extensor performance, enhancing the total number of repetitions performed in the HM and LM conditions, which was significantly higher ($p \leq 0.05$) than that performed in the Control condition (21.5 and 18.1%, respectively). Moreover, there was a significant increase ($p \leq 0.05$) in the average velocity for the whole set in the HM condition in comparison to the LM and Control conditions. This study provides evidence that an HM of vibration generates more neuromuscular facilitation than an LM. These data suggest that a vibration stimulus applied to the feet can result in positive improvements in upper body resistance exercise performance.

Key Words vibration training, WBV, kinematics, elbow extension

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Introduction

In the recent years, research has investigated the application of vibration training (VT) for various fitness improvements. Vibration training has been combined with conventional resistance training in an attempt to attain greater gains in neuromuscular performance than from conventional resistance training alone (20). The effects of VT have been examined after acute and chronic exposure using different protocols and methods. Some studies have analyzed the effect of VT on neuromuscular performance over a period of 6–12 months (8,30,32); however, other studies analyzed the acute effect of VT on neuromuscular performance (2,25–28). The effects of VT are strongly dependent on the vibration parameters (12,22,23,25), namely, vibration frequency, amplitude, duration, and mode. There are basically 3 methods of VT: first, the vibration is applied directly to the muscle belly or the tendon of muscle by a vibration unit (punctual system) (26); second, the vibration enters the human body via hands when griping a vibration dumbbell (7), bar (27) and pulley system (12) (segmental vibration); third, the vibration enters via feet when standing on a vibration platform.

The use of vibration platforms represents the most common form of vibration exercise. There are 2 types of vibration platforms: (a) platforms that vibrate in a predominantly vertical direction (vertical platform) and (b) platforms that vibrate through rotation over a horizontal axis (oscillating platform) (1). Vibration platforms that evoke a mechanical oscillation are defined by frequency and amplitude (6). The frequency is measured in the unit of hertz (Hz) (cycles per second) and shows oscillations ranging from 15 to 60 Hz (6). Peak-to-peak amplitude or displacement is defined as the difference between the maximum and minimum values of periodic oscillation (amplitude is defined as half the difference between the maximum and minimum values of the oscillation) (9). In most studies, amplitude ranges from 1 to 15 mm (6). Maximum acceleration (a_{max}) is dependent upon the frequency and amplitude of the vibration platform (18).

The application of vibration through platforms may limit the range of exercises that can be completed, especially in the upper body. Because of this, most published studies have analyzed vibration effects on the limb that was directly under the vibratory stimuli, for example, studies using vibration platforms have been focused mainly on the effects evoked by vibration over lower-limb strength and power (2,16); effects of a vibrating dumbbell on power and electromyography activity have been studied in arm flexor muscles (5). To our knowledge, no previous studies have measured the effects of vibration stimuli via feet on neuromuscular performance of upper-limb muscles. In this sense, a potential improvement in total volume or kinematic aspects or training sets would be interesting because resistance training variables are directly related to adaptations (3). Thus, this study aimed to analyze the effects of different vibration magnitudes via feet on the number of repetitions performed, mean velocity, and perceived exertion during a set of elbow-extension exercise. It was hypothesized that superimposed vibration would provide an additional stimulus for neuromuscular system, changing the total volume completed, and the kinematic pattern of the set and the perceptual response.

Methods

Experimental Approach to the Problem

Data collection took place over a period of 5 weeks with 1 testing session each week. In the first session, instructions regarding preparation for the 1 repetition maximum (1RM) testing and proper form and elbow-extension technique for the pulley cable machine (Telju, Toledo, Spain) were given to each participant. During the second experimental session, the assessment of the 1RM for the elbow extension was determined. During each of the next 3 testing sessions, 1 set of the elbow-extension exercise was performed until muscular failure on the pulley cable machine. During such a testing sessions, 1 of the 3 conditions was performed: (a) High magnitude (HM) of vibration stimuli, the elbow-extension set was performed with superimposed vibration at 50 Hz and peak-to-peak amplitude 2.41 mm; (b) low magnitude (LM) of vibration stimuli, the elbow-extension set was performed with superimposed vibration at 30 Hz and peak-to-peak amplitude 1.15 mm (LM); (c) control, the elbow-extension set was performed without vibration stimuli. During all experimental sessions, the elbow-extension sets (including the 1RM measurement) were performed on the platform to avoid a setting-related bias. A counterbalance procedure was used to determine the condition for each testing session. Thus, at the end of the experimental phase, all the subjects had been tested for the 3 conditions. Testing sessions were carried out the same day of the week, in all cases at the same time of the day.

Subjects

Twenty recreationally active students (14 men and 6 women) participated in the study. The subjects' mean ($\pm SD$) age, height, body mass, and elbow extension 1RM (on the cable-pulley machine) were 18.9 ± 0.8 years, 175 ± 8.56 cm, 69.5 ± 11.3 kg, and 37.6 ± 13.3 kg, respectively. Subjects were physically active, and all averaged at least 3 months' experience with free-weight resistance exercises and training to failure. Their normal workouts typically lasted just <90 minutes and entailed training of multiple body parts and exercises. However at the time of the study and 2 months before, none was engaged in any regular or organized resistance training program. Subjects had experienced vibration stimulus previously and were provided with several training opportunities to become further accustomed tot the modality. Exclusion criteria were diabetes, epilepsy, gallstones, kidney stones, cardiovascular diseases, joint implants, recent thrombosis, and any musculoskeletal problems that could affect performance. Before data collection, subjects were informed of the requirements associated with participation and provided written informed consent. Moreover, subjects did not allow their sleeping, eating, and drinking habits to change throughout study participation. The research project was conducted according to the Declaration of Helsinki, and it was approved by the University Review Board for research involving human subjects.

Vibration Equipment

The vibration stimulus consisted of uniform vertical oscillations Power Plate® Next Generation (Power Plate North America, Northbrook, IL, USA). The vertical component of the acceleration was measured using an accelerometer in accordance with ISO2954, (Vibration meter, VT-6360, Hong Kong, China). Vibration platform settings included a frequency of 50 Hz with the peak-to-peak amplitude of 2.41 mm (HM) or a frequency of 30 Hz with peak-to-peak amplitude of 1.15 mm (LM). Measured accelerations were 98.55 $m \cdot s^{-2}$ (at 50 Hz and 2.51 mm) and 20.44 $m \cdot s^{-2}$ (at 30 Hz and 1.15 mm) with 70 kg on platform. During all sessions, subjects wore the same athletic shoes to standardize the damping of the vibration because of the footwear (21).

Maximal Strength Measurement

The 1RM elbow extension was estimated from an 1–3RM effort using the equation described by Wathan (33). Each subject carried out 3–5 attempts with progressively increasing weights to achieve a 1–3RM. Three minutes rest was allowed between attempts. Although direct 1RM testing is more reliable, in single-joint assistant exercises (i.e., elbow extension), the 1RM test may present safety issues, and the chosen protocol was thus used to limit risk of injury (4). For elbow-extension repetitions, subjects lowered the bar until the elbows were completely extended. Hand spacing at the handle was shoulder width with the cable perpendicular to the floor when the elbow was flexed 90°. Throughout each repetition, the elbows were flexed and extended equally with the back remaining in contact with the control tower of the platform (see Figure 1). Feet spacing was also shoulder width, and a 30° knee flexion was maintained during the exercise. No bouncing or arching of the back was allowed.

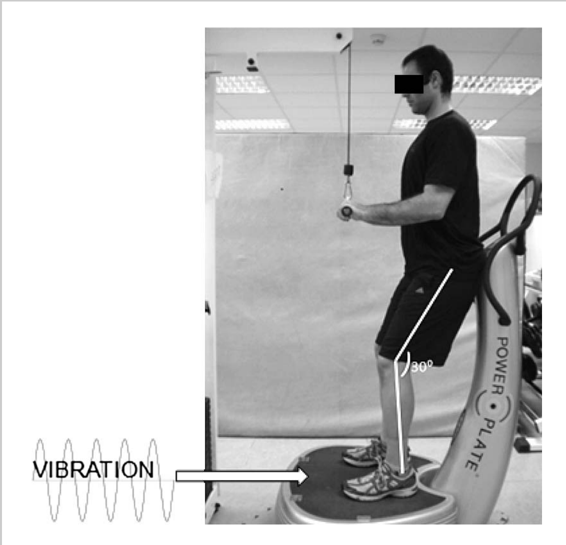

Figure 1. Experimental setup.

Elbow-extension technique and settings were maintained throughout the entire experimental phase.

Elbow-Extension Sets to Failure

Each elbow-extension protocol consisted of performing 1 set to volitional exhaustion, with a load equivalent to 70% of 1RM. In all conditions, subjects began with a warm-up consisting of 5 minutes of low-resistance cycling on an ergometer (50 and 75 W for women and men, respectively), followed by 2 sets of elbow extension comprised of 15 repetitions at 6 kg and 1 set of 10 repetitions at the 40% of the 1RM, allowing 1 minute of rest between sets. In all conditions, individuals began the elbow-extension set to failure on the pulley cable machine at 70% of 1RM 1 minute after the specific warm-up. In HM and LM conditions, the elbow-extension set was performed with superimposed whole body vibration exposure (WBVE). Subjects were asked to move the cable handle as fast as possible during the concentric phase of each repetition, until volitional exhaustion. The elbow-extension range of motion was performed completely, starting from maximal flexion to avoid compensation by the shoulders and/or trunk. Failure was defined, according to a previously established criterion (10), as the time point when the handle ceased to move, if the subject paused more than 1 second when the arms were in the extended position, or if the subject was unable to reach the full extension position of the arms. During the set, 1 examiner encouraged the subjects to execute the exercise properly, with verbal orientations to avoid alterations in posture.

Velocity of each repetition was monitored by linking a rotary encoder (Globus Real Power, Globus, Codogne, Italy) to the highest load plate. The rotary encoder recorded the position of the load plate within an accuracy of 0.1 mm and time events with an accuracy of 0.001 seconds. Mean velocity of the concentric phase of each repetition was recorded for further analysis. Total repetitions performed and average velocity of the whole set were analyzed.

Just after the fifth repetition, the OMNI-RES perceived exertion scale (29) was verbally anchored. OMNI-RES consists of 10 reporting options between 1 (extremely easy) to 10 (extremely hard). All subjects had previous training and experience using the OMNI-RES scale during similar exercise. A written copy of the OMNI-RES scale with the following instructions was given to the subjects: "At fifth repetition, we want you to rate the intensity of effort perceived during the exercise, using the scale shown above. By perceived exertion we mean how heavy and strenuous the exercise feels to you, depending mainly on the strain and fatigue in your muscles and on your general feeling. The value of "1" corresponds to feeling of exertion during seated rest while the value of "10" corresponds to feelings at maximal exertion. You should use the verbal anchors (e.g., extremely easy, extremely hard, etc…) to assist you in giving your perceptions a numeric rating".

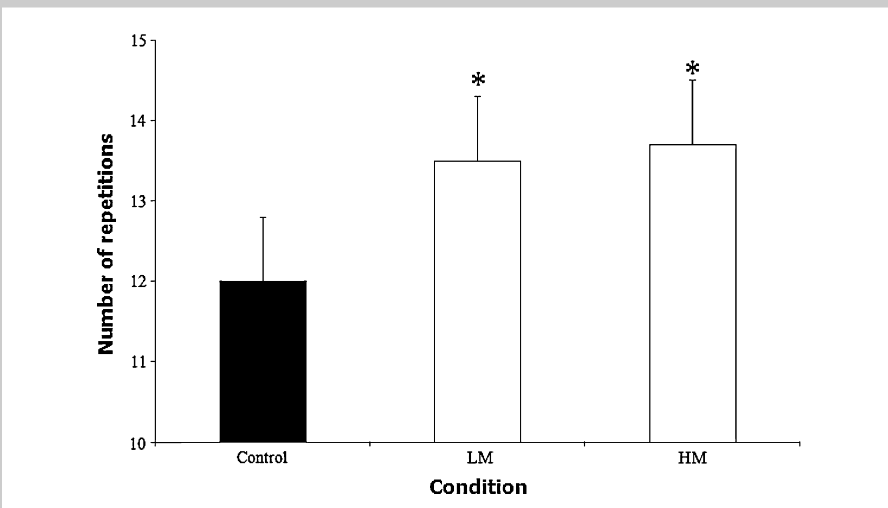

Figure 2. Total number of repetitions. Values are means (*SE*). *Significantly different from control condition ($p < 0.05$).

Statistical Analyses

Normality of the dependent variables was checked and subsequently confirmed using the Kolmogorov–Smirnov test.

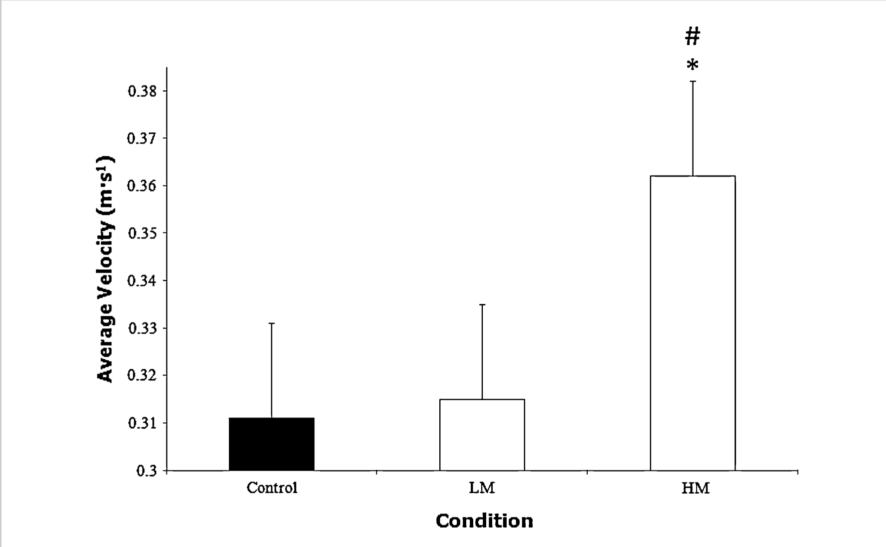

Figure 3. Average repetition velocity during set. Values are means (*SE*). *Significantly different from Control condition ($p < 0.05$). #Significantly different from low magnitude condition ($p < 0.05$).

Comparisons of dependent variables between treatment conditions (i.e., HM vs. LM vs. Control) were analyzed by a 1-way analysis of variance. When a significant *F*-value was achieved, pairwise comparisons were performed using a Tukey post hoc procedure. From the 2 familiarization trials, intraclass correlation coefficients were calculated for each dependent variable to determine test–retest reliability, obtaining values always greater than 0.91. Statistical significance was set at $p \leq 0.05$. Values are expressed as mean ± *SD* in the text and as mean ± *SE* in the figures.

Results

Number of Repetitions and Perceived Exertion

The total number of repetitions performed in the HM and LM conditions was significantly higher ($p \leq 0.05$) than that performed by the control condition (21.5 and 18.1%, respectively) (Figure 2). No statistical differences were found when comparing the HM to LM conditions. Perceived exertion (OMNI-RES value) at the fifth repetition was 7.8 ± 1.2 in the HM condition, 7.7 ± 1.2 in the LM condition, and 8 ± 0.9 in control condition. Although the Control condition was perceived to be slightly harder than the LM condition (3.9%), no significant condition effect was observed ($p > 0.05$) concerning perceived exertion.

Average Velocity throughout the Set

A significant condition effect ($p \leq 0.05$) was observed concerning average velocity (see Figure 3). Post hoc analysis pointed out a significant increase ($p \leq 0.05$) of average velocity for the whole set in the HM condition in comparison to the LM and Control conditions, respectively. On the contrary, no significant differences were found when comparing the LM condition to the control condition.

Discussion

The primary finding of the present study is that the vibration via feet provides superimposed stimuli for elbow-extensors performance, enhancing the number of repetitions completed and the average velocity throughout a set leading to volitional exhaustion. Moreover, this study provides evidence that an HM of vibration (50 Hz and 2.51 mm; 98.55 $m \cdot s^{-2}$) generates more neuromuscular facilitation than a low magnitude (30 Hz and 1.15 mm; 20.44 $m \cdot s^{-2}$). These findings suggest that greater amplitudes may be used during VT to elicit a greater neuromuscular stimulus.

To the best of our knowledge, this is the first study analyzing the effects of superimposed vibration stimuli via the feet on elbow-extensors performance at different magnitudes of vibration. Moreover, previous research focused on the effects of vibration exposure over muscular performance used single-repetition experimental approaches, whereas this study analyzed an entire set with multiple-repetitions, which is the inherent nature of a typical strength-training session. This finding may be of use for several resistance training goals, given that total volume and kinematics associated with resistance exercises (e.g., velocity) have been proposed as important stimuli for strength and muscle power resistance training–induced adaptations (3,24).

Previous studies using segmental vibration (a pulley system at 44-Hz frequency and ~0.6-mm peak-to-peak amplitude; ~30 $m \cdot s^{-2}$) have demonstrated that vibration exposure seemingly results in significant increases regarding muscular performance. Thus, it has been reported that superimposed punctual vibration to a biceps-curl set at 60–70% 1RM improves acute peak power by 10.4 and 7.9% in elite and amateur athletes, respectively (11,13). Along the same lines, a different study pointed out that maximum dynamic strength (100% 1RM) of the elbow flexors was increased by 8.3% in Olympic athletes and 4.9% in amateur athletes when superimposed vibration was applied (17). These results are in line with the present study, in which a significant increase in the total number of repetitions (with HM and LM conditions) and mean velocity (with the HM condition) was observed when the elbow-extension set was performed with superimposed vibration via the feet. On the contrary, Luo et al. found that under 2 loading conditions (40 and 70%

1RM), direct vibration (a portable muscle tendon vibration at 65-Hz frequency and 1.2-mm amplitude) did not enhance the acute neuromuscular performance on power during maximal-effort dynamic bicep curl (19). The different exercise protocols, devices, frequencies, and amplitudes provide a possible explanation for such diverse results.

The mechanisms by which vibration acutely increases neuromuscular performance are poorly understood. There are a few theories on how vibration stimuli can have an effect on the neuromuscular system (20), such as a stimulation of Ia-afferents via spindle, resulting in facilitating homonymous α-motor neurons and/or perturbation of the gravitational field during the time-course of intervention (14). Vibration during exercise is thought to result in short-duration, small and rapid changes in the length of the muscle–tendon complex, in a fashion similar to simulated hypergravity. Mechanical vibration of muscle induces a reflex involuntary contraction (tonic vibration reflex) (25). However, the vibration effect is not only limited to the muscle spindles of the vibrated muscle but also affects those of neighboring and contralateral muscles (15). In this sense, there has been reported a significant augmentation of motor-evoked potentials elicited by transcranial magnetic stimulation when an 80-Hz vibration is applied to extensor carpi radialis muscle, suggesting that vibration increases motor cortex excitability and voluntary drive (31). These findings indicate that vibration in healthy subjects may have an influence on the excitatory state of the peripheral and central structures of the brain, which could facilitate subsequent voluntary movements. This could explain how a vibration stimuli applied mainly to the lower limb (such as the vibration platform used in the present study) could affect upper-limb muscle performance.

In conclusion, it was found that the vibration stimuli via the feet provides superimposed stimuli for elbow-extension performance; additionally, our data point out that high frequency and high amplitude were more effective than low frequency and low amplitude in enhancing the total number of repetition and the average velocity throughout a set leading to volitional exhaustion at 70% 1RM.

Practical Applications

These data suggest that a vibration stimulus applied to the feet can result in positive improvements in the performance of upper body resistance exercise.. They also demonstrate that higher magnitudes of vibration stimulate greater improvements than lower magnitudes. Exercise and fitness professionals can employ HM of vibration at the lower body to improve muscular performance in the upper body. These findings can expand the use of vibration in the upper body, even when specific exercises for the upper body cannot be performed with direct vibration exposure.

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